REPORT DOCUMENTATION PAGE

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OMB No. 0704-0188

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Programmable Logic Controllers for Research on the Cyber Security of Industrial Power Plants

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N00014-15-1-2891

5b. GRANT NUMBER
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5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Rrushi, Julian

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Western Washington University,
516 High Street, Bellingham, WA, 98225-5946

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U.S. Office of Naval Research

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11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; distribution is Unlimited

13. SUPPLEMENTARY NOTES
Report pertains to the entire project duration, which includes a 3 month extension granted in July 2016

14. ABSTRACT
The grant helped us build a control systems research laboratory at Western Washington University. We bought industrial computers from General Electric, Siemens, and Schweitzer Engineering. The lab resembles the control network of a power plant, and includes a small electrical substation control environment. The lab has already been used to support the research of the PI and his student group.

15. SUBJECT TERMS
Industrial control systems, cyber security

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Julian Rrushi
			SAR	15	19b. TELEPHONE NUMBER *(Include area code)* (360)-650-4221

REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on back)

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1.a. NAME OF CONTRACTOR/SUBCONTRACTOR	c. CONTRACT NUMBER	2.a. NAME OF GOVERNMENT PRIME CONTRACTOR	c. CONTRACT NUMBER	3. TYPE OF REPORT *(X one)*
Western Washington University	N00014-15-1-2891			a. INTERIM [ ] b. FINAL [X]
b. ADDRESS *(Include ZIP Code)*	d. AWARD DATE *(YYYYMMDD)*	b. ADDRESS *(Include ZIP Code)*	d. AWARD DATE *(YYYYMMDD)*	4. REPORTING PERIOD *(YYYYMMDD)*
516 High Street, Bellingham, WA, 98225-5946	20150915			a. FROM 20150815
				b. TO 20161114

SECTION I - SUBJECT INVENTIONS

5. "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR/SUBCONTRACTOR *(If "None," so state)*

NAME(S) OF INVENTOR(S) *(Last, First, Middle Initial)* a.	TITLE OF INVENTION(S) b.	DISCLOSURE NUMBER, PATENT APPLICATION SERIAL NUMBER OR PATENT NUMBER c.	ELECTION TO FILE PATENT APPLICATIONS *(X)* d.				CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER *(X)* e.	
			(1) UNITED STATES		(2) FOREIGN			
			(a) YES	(b) NO	(a) YES	(b) NO	(a) YES	(b) NO
	None							

f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR		g. ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED	
(1) (a) NAME OF INVENTOR *(Last, First, Middle Initial)*	(2) (a) NAME OF INVENTOR *(Last, First, Middle Initial)*	(1) TITLE OF INVENTION	(2) FOREIGN COUNTRIES OF PATENT APPLICATION
(b) NAME OF EMPLOYER	(b) NAME OF EMPLOYER		
(c) ADDRESS OF EMPLOYER *(Include ZIP Code)*	(c) ADDRESS OF EMPLOYER *(Include ZIP Code)*		

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			(1) CLAUSE NUMBER	(2) DATE *(YYYYMM)*		(1) AWARD	(2) ESTIMATED COMPLETION
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Grant N00014-15-1-2891 - Project Report

Programmable Logic Controllers for Research on the Cyber Security of Industrial Power Plants

Dr. Julian Rrushi

1 Lab Development

The Defense University Research University Instrumentation Program enabled the PI to develop the cyber security laboratory at Western Washington University. The PI acquired industrial control systems, and thus built a research distributed control system (DCS). The lab was developed in support of research on the cyber security of industrial control systems. The research is being done by the principal investigator and a large group of graduate and undergraduate students. The PI is also developing a course on control systems security, and thus will use the lab to support classes as well. The blueprint that we had designed for our lab is depicted in Figure 1, and now it also resembles our lab. A DCS is used to monitor and control in real-time physical systems within a defined geographic location. It is comprised of devices and network segments distributed through various layers, namely a supervisory level, one or more intermediate supervisory levels, and a field level.

At a supervisory level, system operators use human-machine interface (HMI) applications to send requests over a control network to control servers. Those requests require that the receiving device supplies process data, or that it propagates process set points down to lower levels. A control server in turn requests process data from, or sends process set points to, subordinate control servers at intermediate supervisory levels. Control servers at the lowest intermediate level poll for data or send process set points to programmable logic controllers (PLCs), which receive input from sensors and send output by generating electrical signals in order to drive actuators.

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Table 1 PLCs in our lab.

PLC	Operating System
General Electric PACSystems RX3i	VxWorks
Siemens SIMATIC S7-1500	Siemens Proprietary

ICS protocols	Quantity
Modbus, Serial I/O, SNP	10
PROFIBUS, PROFINET, Modbus, S7comm	7

A PLC may communicate with digital sensors or actuators over a network, which is referred to as fieldbus. Communications over control networks are conducted via protocols such as ModBus, Fieldbus, Distributed Network Protocol v3 (DNP3), while fieldbus communications are conducted via protocols such as DeviceNet or ModBus.

We bought PLCs manufactured by General Electric and Siemens, as detailed in Table 1. The distributors were CBPacific and WESCO, respectively. VxWorks is of particular importance to our projects, as the security tools that we develop require deep knowledge of the operating system. We have received support by the VxWorks maker, Wind River, which has donated to our lab VxWorks virtual machines for code development, as well as VxWorks documentation. The S7 operating system is also of interest to our lab, since S7 controllers are frequently compromised by automated attack code.

Internally, these PLCs have similar architectures. Their internal design follows a von Neumann architecture, which we have depicted in Figure 2. Figure 2 depicts also their I/O modules, which enable them to receive input from, and send output to physical processes usually through electrical signals. The I/O cards of these PLCs can be connected through wiring to sensors and actuators. These PLCs may also communicate with sensors and actuators via a fieldbus communication network. The control applications of these PLCs may be written in one or more programming languages of the IEC-61131-3 industrial standard. The C and C++ languages are also commonly used to program these PLCs.

Since a power plant always includes an electrical substation, we created a computer environment that is similar to that of a real-world electrical substation. We bought protective relays from Schweitzer Engineering. The distributor was Peak Measure. The main characteristics of the substation testbed in our lab are summarized in Table 2. More specifically, the SEL-487E-3 is a protective relay that can monitor and protect a power transformer from electrical faults. It runs intelligent algorithms to detect various types of faults, and can take action in a timely manner by operating electrical circuit breakers and disconnect switches. The SEL-421-4 can perform industrial automation functions. It includes 32 programmable elements for local control, remote control, automation latching, and protection latching. A SEL-421-4 can also conduct various functions to protect overhead electrical transmission lines and underground cables.

The SEL-3355 conducts multiple substation functions too. It has an integrated human-machine interface (HMI), with a local display port. In this

Table 2 Substation controllers in our lab.

Machine	ICS function	ICS protocol
SEL-3555	Automation controller, HMI visualization, data concentrator,	IEC 61850
SEL-487E-3	Transformer protection relay	IEC 61850
SEL-421-4	Protection, automation, and control system	IEC 61850
General-purpose Windows server	OPC server	OPC, IEC 61850
General-purpose Windows client	OPC client	OPC
General-purpose Windows machine	Development and testing	OPC, IEC 61850

work, the SEL-3355 was used as a real-time automation controller. The SEL-3355 polls the SEL-487E-3 and SEL-421-4 to collect substation data from them. The network communications between these ICSs take place over the IEC 61850 protocol. IEC 61850 is a virtual protocol, and thus cannot be used alone for concrete network communications. It needs an actual carrier protocol. Consequently, IEC 61850 is mapped to a protocol stack comprised of the Manufacturing Messaging Specification (MMS), TCP/IP, and Ethernet. MMS was designed specifically for transferring in real time physical process data and supervisory commands. MMS has object models and services that can easily accommodate those of the IEC 61850 standard.

We integrated an engineering server into the substation testbed. The engineering server hosts an OPC server, which in turn runs an IEC 61850 protocol driver to get substation data from the protective relays. The IEC 61850 protocol driver subsequently stores those substation data in the OPC server as data items. We added to the testbed an OPC client machine. The OPC client application has a graphical user interface for a human operator to enter commands using a keyboard and mouse. All machines in the testbed are connected on a local area network.

2 Equipment Already Used in Research

The PI and his student team have already used the controllers acquired through the funding of this grant to support applied research in the lab. We ran several malware experiments in the testbed shown in Figure 3. We obtained those malware samples from public research malware repositories. Furthermore, we emulated the data interception phase of a malware attack on a protective relay. The test exploits were preceded by a scanning with the `nmap` tool of a range of internet protocol (IP) addresses and their services in the lab. We also emulated the malware installation phase, in which the exploit injects and runs a dropper on a compromised protective relay. As in traditional malware, the dropper is responsible for installing the malware modules on the compromised protective relay. We emulated both a single-stage dropper and a dual-stage dropper. The single-stage dropper incorporated the emulated malware modules that it aimed at installing on the compromised protective relay, whereas the dual-stage dropper downloaded those modules over the network from another compromised machine in the testbed. We used all those experiments to

validate a line of work that creates and operates decoy I/O and industrial mirage to intercept at various ranges the ICS malware bound for the power grid. Decoy I/O resemble their respective counterparts, and are implemented in the kernel of the operating system. Industrial mirage, i.e., phantom substation targets for ICS malware to pursue, is realized via power system simulation along with IEC 61850 and OPC traffic emulation. The approach is able to actively redirect ICS malware to decoys, and can sustain prolonged interaction with ICS malware. Currently, the controllers are being used in our lab to support several other research approaches.

3 Timeline of PI Activities

The grant had a duration of 1 year, and began around the end of the summer 2015. In September 2015, the PI encountered a delay in the processing of his work visa renewal, with the consequence being that he could not work at WWU. Shortly after the beginning of the Fall 2015 quarter, the PI entered a period of unpaid leave of absence, which took most of the Fall 2015 quarter. The PI returned for the last couple of weeks of the Fall 2015 quarter, however had to spend all of his time on his teaching load. A back up of assignments, quizzes, and exams, was created, which required immediate solution.

The PI worked in the Winter 2016 quarter on reviewing industrial control systems from several vendors. Elements of interest were the operating system details, industrial code programming environments, industrial communication protocols, and the hardware of industrial control systems. By the end of the Winter 2016 quarter, the PI had developed a list of industrial control systems that could support research projects on the cyber security of the power grid.

In the Spring 2016 quarter, the PI had various negotiations with NAYAK Corporation about buying equipment called RTDS. It is a single platform machine, but quite useful in terms of research support capabilities. Most of the Universities that conduct research in the area of power grid cyber security have bought one. Finally, NAYAK Corporation gave a demonstration at the University of Washington in Seattle, department of electrical engineering. The PI travelled to Seattle to attend the demo, and met with representatives of NAYAK Corporation in person. After a day-long series of demos and meetings, the PI returned to WWU with final negotiation terms on the part of NAYAK Corporation. NAYAK Corporation was very generous when offering to donate the software, however asked that we buy the hardware of RTDS. They prepared a quote, amounting to almost $100K. The PI performed an assessment of the overall situation, and deemed that the quote was prohibitive for our current grant capabilities. The PI decided not to buy RTDS at the time, however will consider it in the future as new grants may be won.

The PI spent the Summer 2016 quarter, as well as the first weeks of the Fall 2016 quarter, on negotiating with sales representatives of various control system vendors. Most of the time that elapsed was due to the sales representatives needing time to prepare the quotes for our consideration. There was also

another factor that took time, namely the PI asked for academic discounts. That needed to be reviewed and approved by the control system vendors, and the sales representatives could not do much except relay the PI's request for academic discounts to those vendors. The last weeks of the project were needed by WWU for internal reviews of the quotes, as well as for the processing of the purchase orders.

4 Appendix

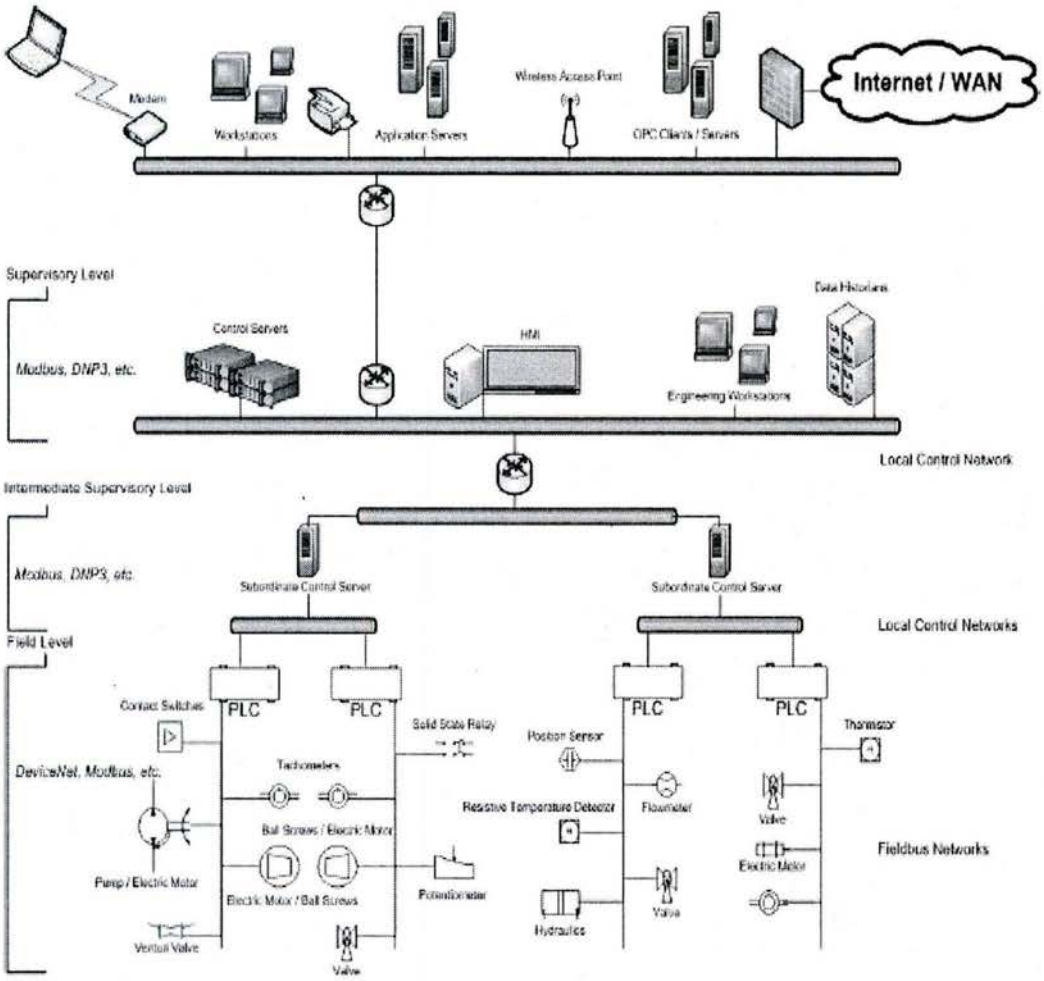

Fig. 1 Distributed Control System

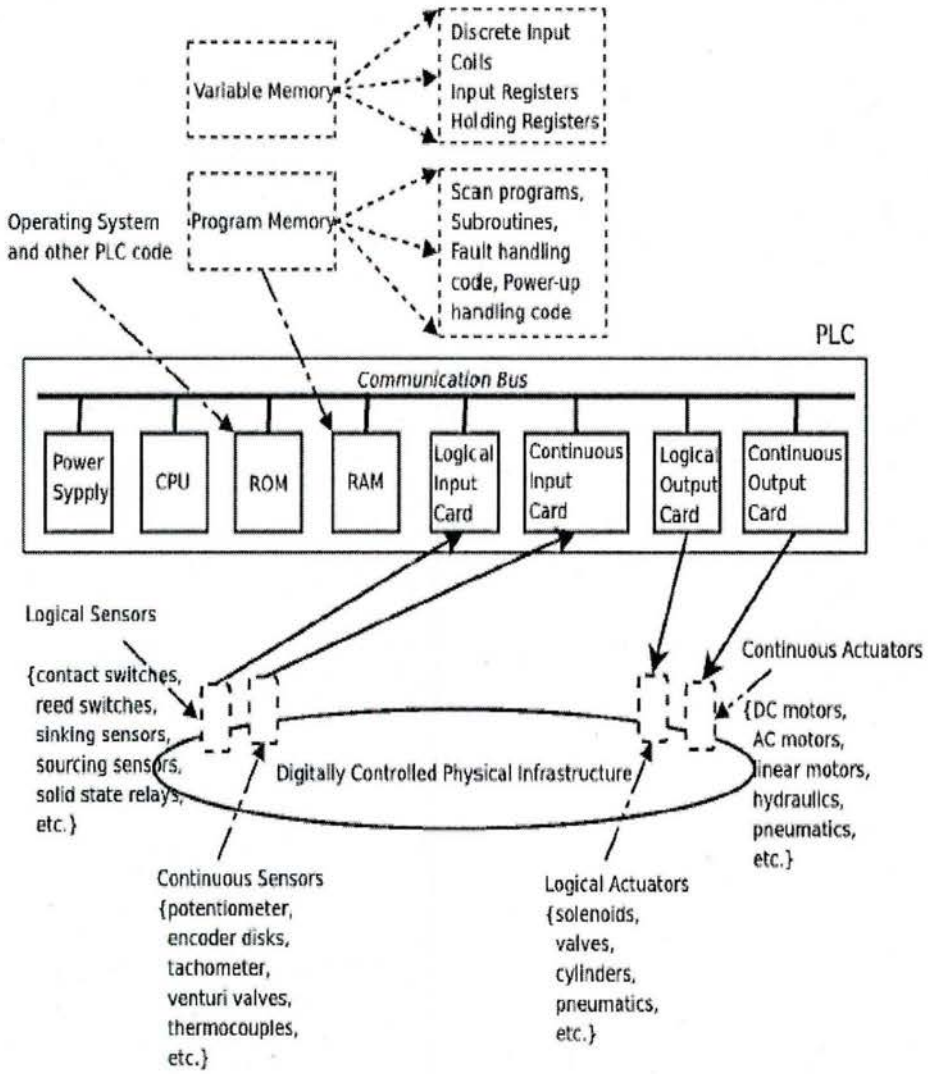

Fig. 2 Programmable Logic Controller

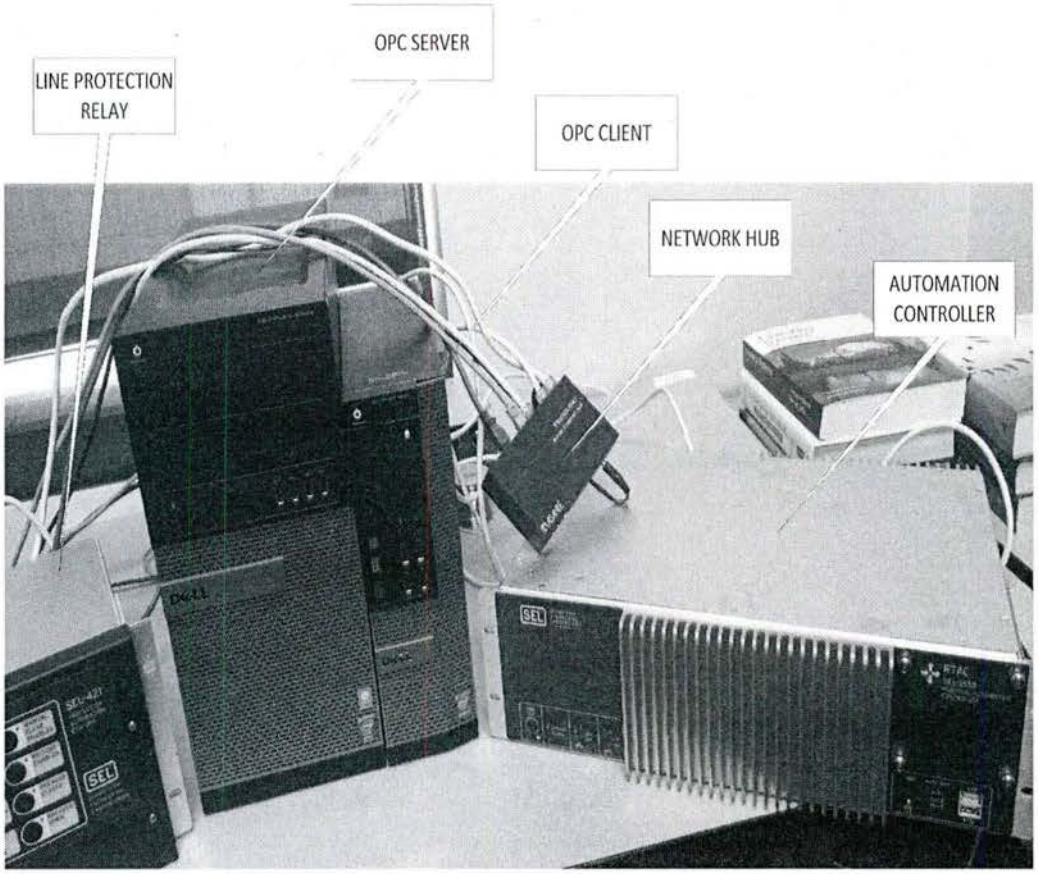

Fig. 3 Substation testbed.

CB Pacific

Quote

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Kirkland WA 98033
Phone: 425.822.1702
Fax: 425.822.5442

#QP81618286
Version #1
08/18/2016

Prepared For
Western Washington University
516 High Street
Bellingham WA 98225
United States

Attention: Julian Rrushi

Expiration Date	Terms	FOB	RFQ or Reference ID
11/30/2016	Net 30	Factory	

Additional Notes | **Delivery Notes**

Line	Model Number	Qty	Unit Price	Ext Price
1	**IC695CHS007** 7 Slot Universal Base. Slot 0 limited to power supply (IC695PSxxx) only and slot 6 is a PCI slot only (IC695xxx). Slots 1 through 5 support both PCI and high speed serial connection (IC695xxx and IC694xxx)	10	$172.80	$1,728.00
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3	**IC695CPE305** CPE305 single slot CPU with 1.1Ghz processor and 5 Meg of user memory. GE University Training Program Special Pricing.	10	$972.00	$9,720.00
4	**IC694ACC300** Input simulator module, 16 points. GE University Training Program Special Pricing.	10	$118.44	$1,184.40
5	**IC694MDL940** Output module, relay 2 amp 16 point, non isolated. GE University Training Program Special Pricing.	10	$105.48	$1,054.80
6	**IC695ALG600** UNIVERSAL ANALOG MODULE. 8 CHANNELS OF ANALOG CONFIGURABLE FOR THERMOCOUPLE,RTD, RESISTIVE, CURRENT, OR VOLTAGE. 2 ISOLATED GROUPS, 4 CHANNELS PER GROUP. Terminal block ordered separately. GE University Training Program Special Pricing.	10	$430.92	$4,309.20
7	**IC695ALG704** Analog Output Module, 4 channels,that is configurable for voltage and current, configured for Current: 0 to 20mA, 4 to 20mA; Voltage: +/- 10 VDC, 0 to 10VDC per channel non isolated. Terminal block ordered separately. GE University Training Program Special Pricing.	10	$313.20	$3,132.00
8	**IC694TBB032** Box Style High Density Terminal Block - 36 Connections. GE University Training Program Special Pricing.	20	$20.88	$417.60
9	**ME90MBP001** Machine Edition v9.0 Professional Development Suite - Annual license fee per training workstation. GE University Training Program Special Pricing.	10	$50.85	$508.50
10	**Freight-TBD** Shipping and Handling - TBD	1	$0.00	$0.00

Prepared by Dale Keister at (425) 429-7782, dale.keister@cb-pacific.com. Account Manager is Michelle T Hammer.
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Quote

#QP81618286
Version #1
08/18/2016

Subtotal	$24,239.70
Tax (0%)	
Total	$24,239.70

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3 pages including this sheet

Date: September 26, 2016

To: Julian Rrushi, Assistant Professor
Department of Computer Science
Western Washington University

Copy: Geoff Davidson

From: Dan Stewart

Subject: Special Educational pricing on bundled hardware and software

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		Sub Total		**$15,700.00**

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7. Cancellation. Buyer may cancel its order for Goods and/or Services, but only if WESCO agrees to such cancellation in writing and only after Buyer pays reasonable charges for expenses already incurred and commitments made by WESCO in connection with the placement of such order(s).

8. Disclaimer of Warranties. WESCO HEREBY EXPRESSLY DISCLAIMS AND EXCLUDES ANY AND ALL REPRESENTATIONS AND WARRANTIES, WHETHER WRITTEN OR ORAL, WHETHER EXPRESS OR IMPLIED, WHETHER ARISING BY CONTRACT, AT LAW, IN EQUITY, BY STRICT LIABILITY OR OTHERWISE, WITH RESPECT TO THE GOODS AND SERVICES, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTY OF MERCHANTABILITY, ANY WARRANY AGAINST DEFECTS IN DESIGN, MATERIALS AND WORKMANSHIP, ANY WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, ANY WARRANTY AGAINST REDHIBITORY DEFECTS, ANY WARRANTY OF GOOD TITLE, AND ANY WARRANTY AGAINST INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY, INCLUDING, WITHOUT LIMITATION, ANY PATENTS, TRADEMARKS, OR COPYRIGHTS. WESCO shall, however, if given prompt written notice by Buyer of any claim of alleged patent, trademark or copyright infringement with respect to any Goods use its reasonable efforts to secure for Buyer such indemnity rights as the manufacturer may offer with respect to such Goods.

9. Exclusive Remedy. Buyer's **EXCLUSIVE** remedy against WESCO for any claim for, or arising out of any in a Good tendered to Buyer is the repair or replacement of the Good, or alternatively, at WESCO's sole election, a refund of the purchase price of the Good. Buyer's **EXCLUSIVE** remedy against WESCO arising out of any defect in, or in connection with, any Service provided hereunder is the re-performance of that Service or, at WESCO's sole election, a refund of the purchase price of the Service. These remedies only will only be available to Buyer for one year after the Good is tendered or Service is provided to Buyer, and WESCO's obligations under this Section 9 will be void unless Buyer provides WESCO with notice of the defect in the Good or Service within 30 days of discovery of the defect. Any Good returned to WESCO for repair, replacement or refund under this Section 9 will be returned by Buyer in accordance with WESCO's return material authorization procedures then in effect, Returns for a refund may be subject to restocking fees..

10. Limitation of Liability. NOTWITHSTANDING ANYTHING ELSE CONTAINED HEREIN TO THE CONTRARY, IN NO EVENT WILL: (A) WESCO BE LIABLE TO BUYER FOR ANY CIRCUMSTANTIAL, CONSEQUENTIAL, CONTINGENT, EXEMPLARY, INCIDENTAL, INDIRECT, LIQUIDATED, MATERIAL, PUNITIVE, SPECIAL, SPECULATIVE OR OTHER DAMAGES, INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOST PROFITS, SALES OR REVENUES, COST OF REPLACEMENT GOODS, LOST BUSINESS OR BUSINESS INTERRUPTIONS, OR ATTORNEYS FEES OR COURT COSTS ARISING IN ANY MANNER PURSUANT TO OR IN CONNECTION WITH THE AGREEMENT, THE GOODS OR THE SERVICES (EVEN IF WESCO IS MADE AWARE OF THE POTENTIAL FOR SUCH DAMAGES); AND (B) WESCO'S TOTAL LIABILITY RELATED TO ANY GOOD OR SERVICE EXCEED THE PURCHASE PRICE OF SUCH GOOD OR SERVICE.

11. Indemnification.

A. Upon prompt notice by Buyer of any claim of U.S. patent, copyright, or trademark infringement with respect to any Goods or Services, WESCO will use its reasonable efforts to secure for Buyer such indemnity rights as the manufacturer may customarily give with respect to such Goods. This Section 10 sets forth Buyer's sole and exclusive remedy against WESCO regarding the infringement by any Goods or Services of any third party intellectual property rights, including, without limitation, any patents or trademarks.

B. Buyer will indemnify, defend and hold harmless WESCO, its shareholders, officers, directors, employees, agents and representatives from and against all losses, damages, liabilities, costs, and expenses including, but not limited to, property damage, loss of profits or revenue, loss of use of any property, cost of capital, cost of purchased or replacement power or temporary equipment, personal or bodily injury, or death ("Losses"), that may arise pursuant to or in connection with the Agreement, the Goods, or the Services (including, without limitation, Losses arising in connection with the performance of Services on Buyer's premises by WESCO's employees, representatives, agents, or subcontractors), regardless of whether such Losses are suffered directly by Buyer or arise pursuant to or in connection with a third-party suit, claim, counterclaim, demand, judgment or other action (each a "Claim") and regardless of whether or not WESCO or any third-party is proportionately negligent with respect to such Losses and/or Claim, provided that Buyer need not indemnify WESCO for WESCO's obligation, if any, to Buyer under Section 9 above. For the avoidance of doubt and without limitation, this indemnification obligation requires Buyer to pay any judgments against WESCO or any other indemnified party resulting from any Claim, any court costs of WESCO or any other indemnified party in connection with any Claim, and any reasonable attorneys' fees and disbursements incurred by WESCO or any other indemnified party in WESCO's defense of any Claim. WESCO will have the sole and exclusive right to conduct the defense of any Claim at Buyer's sole and exclusive cost and expense. Buyer's indemnification obligation does not depend on the truth or accuracy of any allegations made against WESCO, Buyer or any third party.

12. Product Suitability. Goods sold by WESCO are designed to meet stated U.S. safety standards and regulations. Because local safety standards and regulations may vary significantly, WESCO cannot guarantee that the Goods meet all applicable requirements in each locality. Buyer assumes responsibility for compliance with such safety standards and regulations in the localities in which the Goods will be shipped, sold and used. Before purchase and use of any Goods, Buyer should review the product application, and national and local codes and regulations, and verify that the use and installation of the Goods will comply with them.

13. Ownership. WESCO shall have and retain all right, title, and interest in and to any and all trade secrets, technical data, sales service and product plans, methodologies, techniques, designs, molds, tools, samples, systems, know-how, expertise and other proprietary information that it may use pursuant to or in connection with any Services, and Buyer shall not obtain a license to, or any other property rights in, any such WESCO property pursuant to or in connection with this Agreement.

14. Export Controls; Availability; Laws.

A. Certain Goods may be subject to export controls under the laws, regulations and/or directives of the United States and various other countries. Buyer must comply with such laws and regulations and not export, re-export or transfer these Goods to any country to which such export, re-export, or transfer is forbidden or without first obtaining all required authorizations or licenses.

B. Due to government regulations and product availability, not all goods sold by WESCO may be available in every area.

C. Buyer hereby warrants and represents that it will comply with any and all Laws with respect to the purchase, use, and operation of any and all Goods and Services. For purposes hereof, "Laws" means any international, multinational, national, foreign, federal, state, municipal, local (or other political subdivision) or administrative laws, constitutions, statutes, codes, ordinances, rules, regulations, requirements, standards, policies or guidances having the force of law, treaties, judgments or orders of any kind or nature whatsoever, including, without limitation, any judgment or principle of common law.

15. Interpretation of the Agreement. None of WESCO's or Buyer's shareholders, directors, officers, partners, managers, employees, agents or representatives have any authority to orally modify or alter in any way the terms and conditions of the Agreement. The terms, conditions, and limitations set forth in the Agreement can be modified, altered, or added to only by a subsequent written instrument signed by an authorized representative of WESCO or by language included on the face hereof. Regardless of how many times Buyer purchases, or has purchased, goods and services from WESCO by whatever means, each time Buyer accepts the Agreement, Buyer and WESCO enter into a separate agreement that will be interpreted without reference to any other agreement between Buyer and WESCO, or what Buyer may claim to be a course of dealing or course of performance that has arisen between Buyer and WESCO. No inconsistent usage of trade or industry custom, if any, prior to, contemporaneous with or subsequent to the making of the Agreement will waive, vary, serve to explain or serve to interpret any of the terms, conditions and limitations of the Agreement. The Agreement is the sole and exclusive agreement with respect to the matters discussed herein and the provision of Goods and Services hereunder, (except for any contemporaneous writing agreed to in writing by WESCO expressly modifying the terms and conditions hereof, which is hereby incorporated herein by reference and made a part hereof) and supersedes all prior and contemporaneous agreements and understandings, negotiations, inducements, representations or conditions, whether oral or written, whether express or implied, with respect to such matters. Failure by WESCO to enforce any of the terms, conditions and limitations of the Agreement will not constitute a waiver of those terms, conditions and limitations or a waiver of any other terms, conditions or limitations of the Agreement, and the failure of WESCO to exercise any right (whether provided by the Agreement, law, equity, or otherwise) arising from Buyer's default under the Agreement will not constitute a waiver of that right or any other rights.

16. Force Majeure. WESCO will not be liable for its failure to perform under the Agreement (including, without limitation, the failure to deliver any Goods or perform any Services) due to circumstances beyond its control, including, without limitation, fire, flood, earthquake, pestilence or similar catastrophe; war, act of terrorism, or strike; lack or failure of transportation facilities, shortage of suitable parts, materials or labor; any existing or future law, rule, regulation, decree, treaty, proclamation, or order of any governmental agency; inability to secure fuel, materials, supplies, equipment or power at reasonable prices or in sufficient amounts; act of God or the public enemy; or any other event or cause beyond WESCO's reasonable control, including, without limitation, any delay caused by Buyer (each, a "Force Majeure Event"). If any Force Majeure Event prevents WESCO's performance of any of its obligations under the Agreement, WESCO will have the right to (a) change, terminate or cancel the Agreement, or (b) omit during the period of the Force Majeure Event all or any portion of the quantity of the Goods deliverable during that period, whereupon the total quantity deliverable under the Agreement will be reduced by the quantity omitted. If WESCO is unable to supply the total demands for any Goods to be delivered under the Agreement due to a Force Majeure Event, WESCO will have the right to allocate its available supply among its customers in whatever manner WESCO deems to be fair and equitable. In no event will WESCO be obligated to purchase materials from other than its regular sources of supply in order to enable it to supply Goods to Buyer under the Agreement. No change, cancellation or proration by WESCO will be deemed to be a breach of any clause, provision, term, condition, or covenant of the Agreement.

17. Choice of Law; Choice of Venue. The negotiation, execution, performance, termination, interpretation and construction of the Agreement will be governed by the law of the Commonwealth of Pennsylvania, except for Pennsylvania's choice of law rules, and expressly excluding the United Nations Convention on Contracts for the International Sale of Goods. If either WESCO or Buyer brings a lawsuit or any other action arising out of the Agreement against the other party, such party must file its lawsuit or other action in a state or federal court located in Pittsburgh, Pennsylvania. WESCO and Buyer expressly submit to the exclusive jurisdiction of those courts and consent to venue in those courts, and WESCO and Buyer consent to extra-territorial service of process on WESCO and Buyer. In the event of litigation pertaining to any matter covered by the Agreement, each of WESCO and Buyer hereby agree to waive any right that it may have to a jury trial of any or all issues that may be raised in such litigation. Nothing contained in the Agreement will be construed to limit or waive any rights of WESCO under applicable United States federal, state, or local laws. Any provision of the Agreement held to be invalid, illegal or unenforceable will be ineffective to the extent of such invalidity, illegality or unenforceability without affecting the validity, legality and enforceability of the remaining provisions hereof.

18. Binding Authority. Any director, officer, employee, representative, or agent of Buyer signing or otherwise entering into this Agreement hereby represents and warrants that he or she is duly authorized to execute and enter into this Agreement on behalf of Buyer.

PEAK MEASURE
www.peakmeasure.com

Manufacturers' Representative
PO Box 970, Ridgefield, WA 98642
Phone 360-263-0123 Fax 360-263-0124

QUOTATION

Prepared For:
Julian Rrushi
WWU
360-650-4221
julian.rrushi@wwu.edu

End User/Project:

Please Address PO to the Vendor:
Schweitzer Engineering Laboratories
c/o PEAK Measure
2350 NE Hopkins Ct, Pullman, WA 99163

Please Submit PO's and RFQ's to:
orders@peakmeasure.com

One-Time 50% Discount Applied

Quote Date: 7/28/2016
Quote #: QSEL-160728-M4
Exp. Date: 9/26/2016

Prepared By:
Michelle Conley
Peak Measure
360-263-0123
michelle@peakmeasure.com

Item	Qty	Part Number	Description	Unit Price	Ext Price
1	1	3555#HH9H	SEL-3355 Powerful. Rugged. Reliable. Designed as a server-class computer	$8,630.00	$8,630.00
2	1	0487E3X211XXC4X1H621XXX KEY 8799	SEL-487E-3, Transformer Protection Relay	$4,160.00	$4,160.00
3	1	04214211XC4X1H21XXXXX KEY 6422	SEL-421-4, Protection, Automation, and Control System	$4,150.00	$4,150.00

NOTE: Most SEL products come standard with a CD manual.
One complimentary printed instruction manual is available upon request with each product purchased.

Total: $16,940.00

Estimated Lead Time: Up to 30 business days

Freight Prepaid & Allowed within the Continental USA via FedEx Ground; otherwise Prepaid & Added.

Freight Prepaid & Added to Alaska via FedEx 2-Day unless the customer requests a different method.

Please submit PO's to orders@peakmeasure.com.

> PO must be addressed to Schweitzer Engineering Laboratories or SEL as the vendor.

> PO must specify Net 30 as the Terms.

> PO must include complete part numbers and unit prices for each line item.

Quote is subject to all current SEL Sales Terms, available upon request.
Lead times are not guaranteed and do not include shipping time.
Prices are based on quantities quoted and may change if quantities change.
It is the customer's responsibility to order the exact configuration required.
In the event of errors or omissions, this offer is void and will be corrected on request.